VOL. 17, NO. 12, JUNE 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

PROPOSAL OF AN AUTOMATED TOOL FOR THE ANALYSIS OF USABILITY TESTS

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ABSTRACT

With the increase in the number of users consuming interactive applications and the growth of apps in the app stores, usability has become one of the key factors that allow software development companies to be competitive in the market and users to be productive. To evaluate the usability of a software product, the so-called user tests are used, in which a set of users perform a certain number of tasks while interacting with an interactive application, in order to determine the level of usability based on the calculation of the attributes of efficiency, effectiveness and satisfaction. In this paper, we propose as a contribution the development of an automated tool for the analysis of usability tests, which receives as input the parameters associated with the attributes of effectiveness, efficiency and satisfaction, obtaining as output the level or percentage of usability for the software evaluated in the test. This tool is intended to support usability test coordinators in automating the test analysis process and determining the usability level of an interactive application. This tool can also be considered as a reference for the automation of other types of usability tests, such as heuristic evaluations or usability inspections.

Keywords: effectiveness, efficiency, satisfaction, user tests, usability.

INTRODUCTION

With the increase in the number of applications developed and published in digital repositories, as well as in the number of users that consume them, one of the key factors that allows for improving both the competitiveness of companies in the software field, as well as the productivity of end users, is usability [1]-[3]. In this sense, usability is considered an attribute that defines software quality according to ISO 9126-1 and can be understood as the ability of software to be understood, learned and used in a simple and attractive way [4]-[8]. Similarly, according to ISO 9241-11 usability can be defined as the extent to which a software product can be used by specific users to achieve its objectives with: effectiveness, efficiency and satisfaction in a specific context of use [9]-[12]. Thus, the three attributes that define the usability of a software product are effectiveness, efficiency and satisfaction [13]-[15].

Usability can be considered in the software development process, both in the design phase and in the evaluation phase[16]. Thus, in the design phase, usability can be considered through the inclusion of a set of heuristics or design guidelines, while in the evaluation phase it can be considered through the development of so-called usability tests. Within a usability test or user test, the tasks performed by a group of users in a controlled environment or usability laboratory are monitored in order to obtain the attributes of effectiveness, efficiency and satisfaction[17], [18]. Effectiveness can be determined through the number of tasks completed properly, efficiency can be determined by relating the time spent by the user in developing a task with respect to the time estimated by the test coordinators, while satisfaction is obtained through the use of perception questionnaires after the completion of the tasks by the user within the test [19], [20].

Within usability testing, one of the existing challenges is to have tools that allow automating the different processes of analysis of the data collected in the tests in order to obtain a level of usability, based on the calculation of the attributes of effectiveness, efficiency and satisfaction. Thus, in this paper, we propose as a contribution, the development of a tool that allows the coordinators of a usability test to automatically determine the values of the attributes of effectiveness, efficiency and satisfaction, as well as the level of usability estimated from these attributes for the software evaluated in the test. In this way, the tool first takes as input different test configuration parameters, such as: the number of users, the number of tasks, the number of subtasks of each task, the estimated time to develop each task, the number of questions to be considered in the satisfaction evaluation and finally the weight of each of the 3 attributes (effectiveness, efficiency and satisfaction) in the calculation of the usability level of the software evaluated in the test. Once the above parameters have been defined, the tool allows the test coordinator to fill in different tables: the number of subtasks that each user developed per task, the time spent by each user in solving each task and the score assigned to each of the questions that evaluate satisfaction. Thus, from the above data captured in the test and taking into account the weights assigned to the 3 attributes, the tool allows obtaining an output usability level and a report with the results of the analysis performed. This tool is intended to serve as a reference to be extrapolated to other types of evaluations considered in the context of usability, such as usability inspection and heuristic evaluation.

The rest of the article is organized as follows: first, the methodology used for the development of this research is described. Following the above, the results obtained through this work are presented, which include

the description of the functional structure of the tool, the views that make up the interface of the tool and finally a case study that allows to verify the relevance and usefulness of the proposed tool, through the use of real data from a usability test, in order to determine the level of usability for the evaluated software. Finally, conclusions and future work derived from this research are presented.

METHODOLOGY CONSIDERED

For the development of this research, four methodological phases were defined (see Figure-1): characterization of the user tests, design of the automated tool, construction of the automated tool and finally case study.

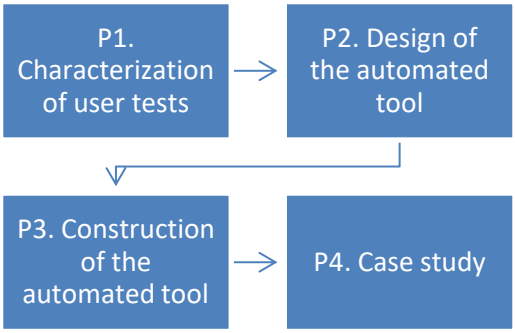


Figure-1. Methodology considered.

Phase 1 of the methodology identified the main characteristics of user tests, in which a group of users perform a set of tasks within an interactive application during a given time in a controlled environment or usability laboratory. These tests are generally developed in four stages: a confidentiality agreement, a pre-test questionnaire, a list of tasks to be performed by the users in the evaluated software and finally a post-test questionnaire [20]. The purpose of these tests is to obtain the usability level of given software by calculating the usability attributes: effectiveness, efficiency and satisfaction, which have been defined by ISO 9241-11. Thus, the level of usability can be obtained from equation (1).

$$U = k1 * \text{Effect.} + k2 * \text{Effic.} + k3 * \text{Satisf.} \quad (1)$$

In equation (1), Effect. corresponds to the percentage of total effectiveness obtained in the usability test. Similarly, in equation (1) Effic. corresponds to the percentage of total efficiency obtained in the user test. On the other hand, Satisf. corresponds to the percentage of satisfaction obtained from the ratings given by the users to the questions that evaluate the user's perception in the post-test questionnaire. The k1, k2 and k3 indexes correspond to a coefficient between 0 and 1 that determines the degree of contribution of each of the three attributes to the calculation of the total usability level of the interactive system evaluated.

The percentage of effectiveness within a usability test can be obtained by averaging the effectiveness per user, which is defined by equation (2), where the number of subtasks performed by the user in each task is related to the number of subtasks defined for each task.

$$\%\text{Effectiveness} = \left(\frac{\text{subtasks performed}}{\text{total subtasks}}\right) * 100 \quad (2)$$

The percentage of efficiency within the usability test is determined through equation (3), in which the estimated time for each task is related to the time spent in performing each task.

$$\%\text{Efficciency} = \left(\frac{\textit{estimated time per task}}{\textit{time spent per task}}\right) * 100 \quad (3)$$

Finally, the percentage of satisfaction within the user test can be determined through equation (4), in which the values obtained in the ratings assigned by the users to the questions that evaluate the perception within the post-test questionnaire are averaged. This average is multiplied by 20 in order to fall within the range of 0 to 100.

$$\%\text{Satisfaction} = \left(\frac{r1+r2+r3+r4+\cdots+rn}{\text{n}}\right) * 20 \quad (4)$$

Once the characterization of the 3 usability attributes according to ISO 9241-11 was completed, phase 2 focused on the design of the automated tool, which included the definition of both the functional structure of the tool and the high-level interfaces that will enable the development of the different functional processes that make up the tool. Based on the views defined in phase 2, phase 3 of the methodology proceeded with the implementation of the different functional modules in the Java programming language. Finally, phase 4 of the methodology focused on the verification of the functionality of the automated tool through its use in the analysis of a usability test developed on an e-commerce portal in Colombia. Thus, the values that allow the calculation of the 3 attributes that define usability, as well as the weight of each attribute within the test (k1, k2 and k3), were provided as input, in order to obtain the level of usability for the e-commerce portal evaluated in the case study developed.

RESULTS AND DISCUSSIONS

This section describes the results obtained from the development of this research, which includes the specification of the functional modules of the proposed tool, the description of the functional processes performed by the tool to obtain the level of usability, the presentation of the different views that make up the tool and finally the description of the results obtained through the case study developed in this research.

Based on the above, Figure-2 shows the five functional modules that make up the proposed automated tool.

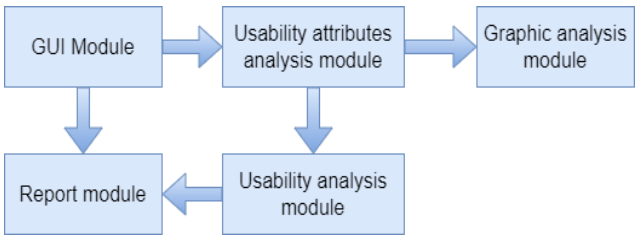


Figure-2. Block diagram of the tool.

The "GUI" module of the automated tool is in charge of displaying the tool interface and managing the different components (buttons, text boxes, text areas, labels), as well as handling the events that allow the user to interact with the interface. Through the interface components generated by this module, the end user (test coordinator) can enter as input the test configuration data (number of users, number of test tasks, number of subtasks for each task, estimated time per task, number of perception study questions, weight of each usability attribute) and fill in the values measured and captured during the test for each user (number of subtasks performed per user, time spent per user to perform the different tasks and rating assigned by each user to the post-test questionnaire questions addressing perception). The GUI module was implemented using the Swing library of the Java language. The "Usability attributes analysis" module is responsible for obtaining the percentage of effectiveness, efficiency and satisfaction attributes through the use of equations (2), (3) and (4), based on the data filled in by the test coordinator and related to the data captured and/or measured from the tasks performed by each user throughout the test. The calculations obtained in this module were performed using the Commons Math library from Apache and compatible with the Java language. The "Usability analysis" module is in charge of determining the usability value of the software evaluated in the test, taking into account the weights of the attributes (k1, k2 and k3) and the percentages of effectiveness, efficiency and satisfaction calculated in the "Usability attributes analysis" module. In the same way, the "Graphic analysis" module is in charge of presenting, by means of a bar chart, the percentages of effectiveness, efficiency and satisfaction, according to the results obtained in the "Usability attributes analysis" module and making use of the J Free Chart Java library. Finally, the "Report" module is in charge of generating a report in .CSV format with the calculations of the percentages of effectiveness, efficiency and satisfaction for each user of the test and with the level of usability obtained throughout the test. For the above, this module makes use of the Java Simple Writer class, which allows writing and reading plain text files.

On the other hand, Figure-3 shows a flow chart that represents the different functional processes developed by the automated tool for the analysis of a user test. In the first instance, the automated tool for usability test analysis is started, after which the test coordinator enters a set of configuration parameters associated with the user test to be analyzed, such as: the number of users of the test, the number of tasks to be developed within the software to be evaluated, the number of subtasks for each test task, the estimated time for each test task, the number of questions of the post-test questionnaire related to the satisfaction attribute and finally the weights (k1, k2 and k3) of the attributes of effectiveness, efficiency and satisfaction in the calculation of usability. Once the above data have been filled in, the tool receives for each usability attribute and for each user the data monitored and captured in the test. Thus, in the case of the effectiveness attribute, the tool receives the number of subtasks performed by each user in a task; in the case of the efficiency attribute, the tool receives the time spent by each user in performing each task of the test; finally, as for the satisfaction attribute, the tool receives the rating given to each question associated with the perception of the post-test questionnaire.

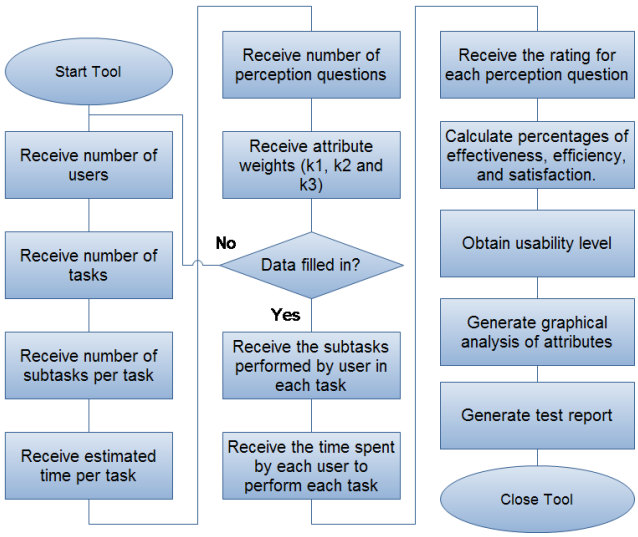


Figure-3. Tool flow chart. Source: own.

Thus, taking into account the data provided by each user of the test, the tool calculates the percentage of effectiveness, efficiency and satisfaction for each user and total. Similarly, from the percentages obtained for each attribute and taking into consideration the weights k1, k2 and k3, the tool calculates the total usability level obtained in the test. In the same way, the tool allows to generate a bar chart with the percentages of effectiveness, efficiency and total satisfaction obtained in the analyzed usability test. Finally, the tool allows the generation of a CSV report including the data captured in the test for each user and the percentage results obtained for the attributes of effectiveness, efficiency and satisfaction. Likewise, the calculated usability level is included in the generated report.

The following are the different views or final interfaces of the automated usability testing analysis tool, which consists of 6 tabs: "Configuration", "Effectiveness", "Efficiency", "Satisfaction", "Total Usability" and "Graphical Analysis", as shown in Figure-4.

The "Configuration" tab shown in Figure-4, is in charge of receiving the different general configuration

parameters associated with a user test, which includes: the number of users of the test, the number of tasks and the subtasks associated with each task, the estimated time for the development of each task, the number of questions to be considered in the post-test questionnaire for the calculation of satisfaction and finally the weights that each usability attribute will have. By pressing the "Configure" button in this tab, the other tabs automatically generate different tables to fill in the data captured in the test for each of the users considered. Thus, as an example, Figure-4 shows the data of a usability test with 3 users, who each developed 2 tasks with an estimated duration of 10 minutes each and with a total of 3 subtasks. Likewise, the test presented in Figure-4 has two perception analysis questions and has a balanced attribute weight of 0.333 (k1, k2 and k3).

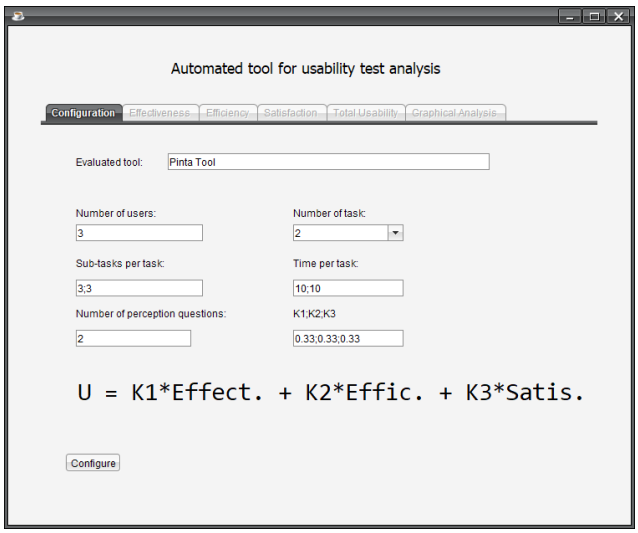


Figure-4. Main tool interface.

On the other hand, in the "Effectiveness" tab, the tool receives the number of subtasks performed by each user in each task, so that by pressing the "Calculate" button it is possible to obtain the percentage of usability per user, per task and for the total test (see Figure-5). Thus, as an example, Figure-5 shows the data filled in at the efficiency attribute level for the user test configured in Figure-4. Thus, from the example data entered in Figure-5, the tool obtains that task 1 and task 2 have an efficiency percentage of 88.889%. Similarly, users 1 and 2 have an efficiency percentage of 83.333%, while user 3 has an efficiency of 100%, which means that this user completed all the subtasks of each task. Based on the above, the overall average effectiveness for the example test is 88.889%.

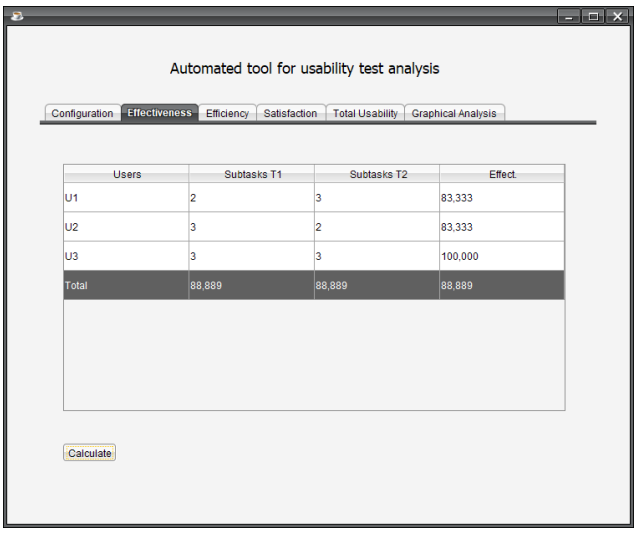


Figure-5. “Effectiveness" tab of the tool.

Continuing with the description of the tool, Figure-6 shows the interface of the "Efficiency" tab, where the times used by each test user to perform the number of tasks defined in the "Configuration" tab are received and the efficiency per user and per task is calculated by pressing the "Calculate" button.

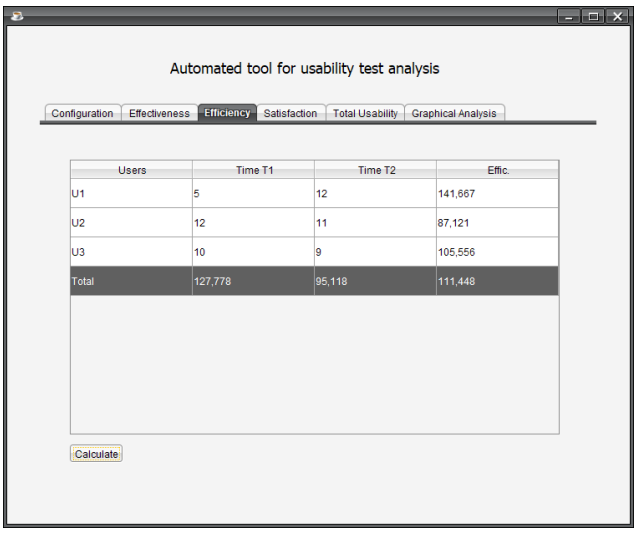


Figure-6. “Efficiency" tab of the tool.

As an example, Figure-6 shows the data at the efficiency attribute level for the user test configured in Figure-4. Thus, it is possible to appreciate from the data in Figure-6 that task 1 has an efficiency of 127.778%, while task 2 has an efficiency of 95.118%. Similarly, it is possible to observe how user 1 presented an efficiency of 141.667%, while user 2 presents an efficiency of 87.121% and user 3 has an efficiency of 105.556%. From the above data, the total efficiency percentage for the example test is 111.448%.

In the same sense, Figure-7 shows the interface of the "Satisfaction" tab, in which the tool receives the ratings assigned by the users regarding the perception of the software evaluated in the test and allows to obtain the

satisfaction per question and per user by pressing the "Calculate" button.

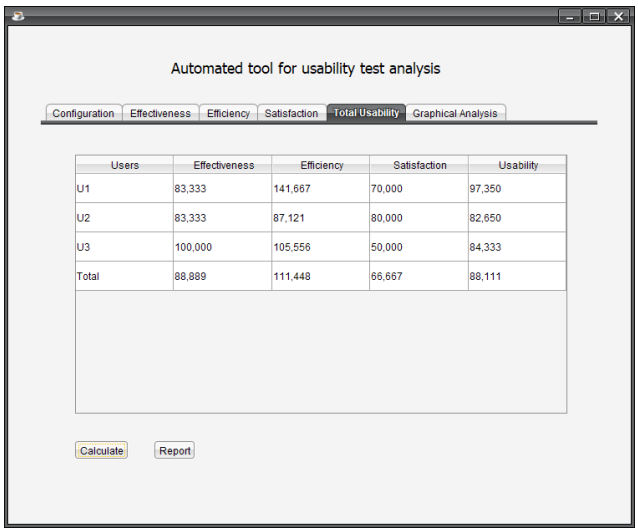


Figure-7. "Satisfaction" tab of the tool.

As an example, in Figure-7, the ratings for the 2 perception questions that were defined in the example test in Figure-4 were filled in. Thus, it is possible to see in Figure-7 how in questions 1 and 2 a satisfaction percentage of 66.667% was obtained. Similarly, it is possible to appreciate that user 1 has a satisfaction rate of 70%, while user 2 has a satisfaction rate of 80% and user 3 has a satisfaction rate of 50%. From the above data, the total percentage of satisfaction for the example test is 66.667%.

Continuing with the description of the tool's tabs, in Figure-8 it is possible by pressing the "Calculate" button to obtain the values of effectiveness, efficiency and satisfaction per user and for the total test. In the same way, the tool determines the usability per user and the total usability of the test by taking into account the values of the weights (k1, k2 and k3). The data calculated in this tab can be saved as a report in a .CSV file. Thus, for the example test data filled out and presented in the previous tabs, the tool obtained a total effectiveness percentage of 88.889%, a total efficiency percentage of 111.448% and a total satisfaction of 66.667%. Similarly, the tool determined that usability for user 1 is 97.350%, usability for user 2 is 82.650% and usability for user 3 is 84.333%, resulting in a total usability value of 88.111.

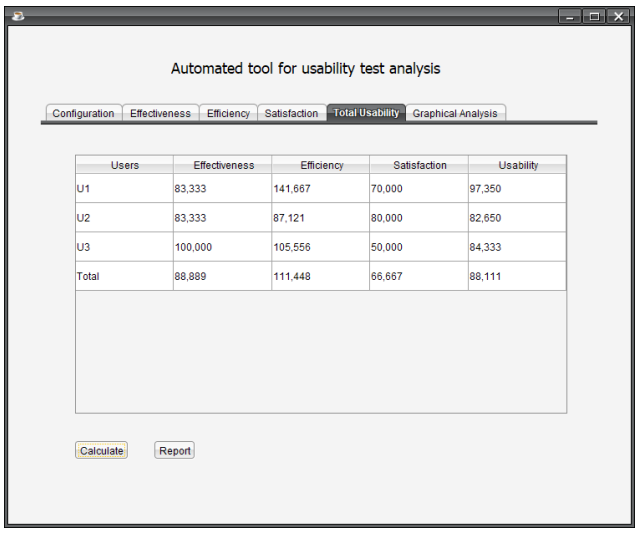


Figure-8. "Total Usability" tab of the tool.

Finally, Figure-9 shows the interface of the "Graphical Analysis" tab, in which the values of the attributes of effectiveness, efficiency and satisfaction obtained in the previous tabs for each of the user of the test are presented by means of a bar chart. Thus, for the example test data, a bar chart shows that efficiency was the attribute that obtained the highest value of the attributes for the three users, while satisfaction is the attribute with the lowest values per user.

Once the different views of the proposed tool were presented, the application of this tool is shown in the analysis of a test with 5 users and 3 tasks developed on the web portal of the Colombian e-commerce company: Sigma Electrónica (see Figure-10).

Figure-9. "Graphical Analysis" tab of the tool.

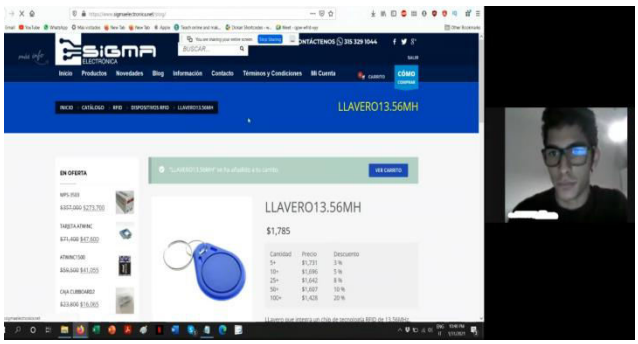


Figure-10. Usability test performed on Sigma Electrónica's website.

Based on the above, Table-1 presents the specification of each test task, including the duration of each task in seconds and the number of subtasks per task.

Table-1. Especificación de las tareas de la prueba.

Tasks	Number of subtasks	Estimated time (sec)
Register on Sigma Electronica's web portal using a test email provided by the test coordinators.	2	180
Interact with the site's shopping cart by searching for three products available in the store.	3	180
Enter the blog section and comment on any of the articles presented there.	2	180

Once the test data had been configured in the automated tool and the data associated with the efficacy attribute captured in the test had been registered, the results presented in Table-2 were obtained through the tool.

Table-2. Obtained results for the effectiveness attribute.

Users	Subtasks T1	Subtasks T2	Subtasks T3	Effect.
1	2	2	2	88.889
2	2	3	2	100
3	2	3	2	100
4	2	3	1	83.333
5	2	3	2	100
Total	100	93.333	90	94.444

Similarly, once the times in seconds used by the users for the development of each of the test tasks were included, the results for the efficiency attribute presented in Table-3 were obtained through the tool.

Table-3. Results obtained for the efficiency attribute.

Users	Time T1	Time T2	Time T3	Effic.
1	62	260	195	150.620
2	19	120	101	425.195
3	115	143	110	148.677
4	120	120	180	133.333
5	22	393	257	311.341
Total	472.479	108.181	120.840	233.833

On the other hand, for the satisfaction attribute, the ratings of 3 of the questions of the post-test questionnaire were included in the tool, obtaining the results presented in Table-4.

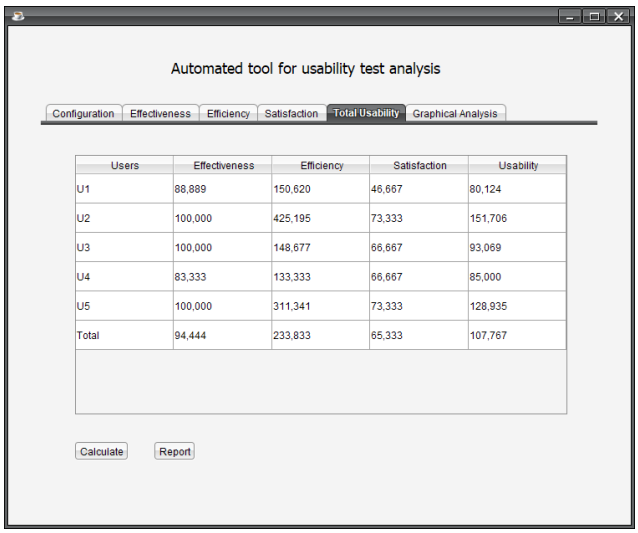
Table-4. Results obtained for the satisfaction attribute.

Users	Q1	Q2	Q3	Satisf.
1	3	2	2	46.667
2	3	4	4	73.333
3	3	3	4	66.667
4	3	3	4	66.667
5	3	4	4	73.333
Total	60	64	72	65.333

Once the results were obtained for the attributes of effectiveness, efficiency and satisfaction, the tool determined the usability per user and the total usability of the test, taking as input the values of k1=0.3, k2=0.2 and k3=0.5. In other words, in the test, satisfaction and effectiveness were considered to have a greater weight than efficiency. Thus, Figure-11 shows the results generated by the tool at the level of usability per user and total.

According to Figure-11, it is possible to appreciate that the user who obtained the lowest percentage of usability was user 1 with 80.124% of usability level, while the user who obtained the highest percentage of usability was user 2 with 151.706% of usability level. At the level of usability attributes, it can be observed that the attribute that obtained the highest percentages was efficiency, which has values greater than or equal to 133.33% for all users.

Similarly, the attribute that obtained the lowest percentages was satisfaction, with percentages between 46.667% and 73.333%. Finally, it can be seen that the total usability obtained in the case study test was 107.767%.



Users	Effectiveness	Efficiency	Satisfaction	Usability
U1	88,889	150,620	46,667	80,124
U2	100,000	425,195	73,333	151,706
U3	100,000	148,677	66,667	93,069
U4	83,333	133,333	66,667	85,000
U5	100,000	311,341	73,333	128,935
Total	94,444	233,833	65,333	107,767

Figure-11. Percentage of usability obtained in the case study.

The above results can be seen more clearly in Figure-12, which graphically shows the percentages of effectiveness, efficiency and satisfaction for each user. This figure shows the contribution of the effectiveness attribute to the final value of usability.

Figure-12. Effectiveness, efficiency and satisfaction percentages for the case study.

CONCLUSIONS

Taking into account the need to automate the analysis of the results of a usability test or user test, in this article, we proposed as a contribution the development of an automated tool that receives as input the general parameters of a usability test such as: number of users, number of tasks, number of subtasks per task, estimated time per task and number of questions that evaluate satisfaction, and then from these parameters and the data captured during the test for each user, calculate the attributes of effectiveness, efficiency and satisfaction, as well as the level of usability obtained per user and in the total test.

An important contribution of the proposal presented in this work is the inclusion of the coefficients k1, k2 and k3, which allow the test coordinator to define the weight of the attributes of effectiveness, efficiency and satisfaction, in determining the percentage of usability within the user test. Thus, the sum of the three coefficients is 1, so that by default each coefficient has a value of 0.333 associated with it, in case the test coordinator considers that the contribution of each attribute to the level of usability is the same.

The Java language and the different libraries used at the level of the graphic interface and mathematical analysis proved to be adequate for the implementation of the automated tool. Also, thanks to the multiplatform advantages of the Java language, the tool can be executed and used in different operating systems by the usability test coordinator. Both the technologies considered in the implementation and the structure of the tool can be taken into account for extrapolation in the automation of other types of tests such as usability inspections or heuristic evaluations.

Through the tool developed, it was possible to automate the process of analyzing the results of a user test carried out on the Sigma Electrónica e-commerce portal. Thus, by using the automated tool, it was obtained that the percentage of effectiveness was 94.444%, the percentage of efficiency was 233.833% and the percentage of satisfaction was 65.333%, resulting in a total percentage of usability of 107.767%, for values of k1=0.3, k2=0.2 and k3=0.5.

Finally, as future work derived from the present research, we intend to extrapolate the automated tool to the context of usability inspections and heuristic evaluations.

ACKNOWLEDGMENTS

The authors would like to thank the Universidad de Cartagena-Colombia and the Universidad del Quindío-Colombia for their support in the development of this research.

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